

# Assessment of passion fruit orchard management and farmers' technical efficiency in Central-Eastern and North-Rift Highlands, Kenya

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## Abstract

In Kenya, passion fruit (*Passiflora edulis* L.) has emerged as an important high market value horticultural crop over the last decade following the establishment and expansion of large scale processors of fruit juice and increasing population of health conscious consumers. This has led to increasing interest in the enterprise among farmers. However, many farmers have also withdrawn from passion fruit farming, citing low productivity of orchards. The objective of this study was to compare management and technical efficiency (TE) of orchards in Central-Eastern (Embu and Meru Counties) and North-Rift (Uasin Gishu County) Highlands of Kenya in order to determine opportunities for increasing and sustaining productivity. Cross-sectional data from 123 randomly selected farmers was collected using a personally administered structured questionnaire and subjected to managerial and stochastic frontier analysis. Management was assessed considering five practices; training of vines and pruning, weeding, watering, disease management and manure/fertilizer application. Meru County had the highest mean TE (65%) followed by Uasin Gishu (57%) while Embu was the least efficient (47%). Mean scores for the five management practices evaluated also followed a similar trend across the three Counties. The five management practices assessed significantly influenced TE. Therefore, the study established a relationship between orchard management practices and TE of farmers. The study recommends promotion of county cross-border farmer linkages as a platform for sharing ideas and success experiences. Further, increased emphasis on frequent farmer update on farming trends through participatory methods (lead farmer approach, training, farm visits and demonstrations) are recommended to increase farmer awareness on appropriate orchard management practices, which would eventually contribute to improved technical efficiencies and productivity.

**Keywords:** Technical efficiency, managerial analysis, stochastic frontier analysis

## 1. Introduction

The horticulture industry sustains millions of livelihoods in Kenya through local and export markets. Passion fruit is one of the most important horticultural crops being ranked third (at 8%) after avocado (62%) and mango (26%) in Kenya in terms of foreign exchange earnings (HCDA, 2011). Passion fruit can realize high yields more regularly since it is in production for at least 6 months (two seasons 3 months each) annually, making it a suitable enterprise for smallholder farmers who are resource constrained. The fruit is produced mostly by smallholder farmers on orchards measuring from 0.10 to 0.81 hectares (Mbaka *et al.*, 2006; Otipa *et al.*, 2009). According to Anderson (2003), and Gockowski and Michel (2004), small holder farmers are faced with limitations such as capital, management skills and storage facilities. Therefore, they need not produce surplus in order to minimize wastage. Timely sale of farmers' produce ensures their little resources are replenished thus enabling provision of capital for other enterprises.

Passion fruit enterprise has higher returns compared to cabbage, maize, wheat, tomatoes and beans (Kibet, 2011) if production is carried out efficiently especially in the first production year with expected increase in returns during the second and third years of production (Fintrac, 2009). The enterprise can attain a gross margin of Ksh. 629,850 per hectare (US \$7,410). Therefore, the enterprise presents a quick avenue to poverty alleviation, creation of employment and improved food security (Kibet *et al.*, 2011). However, inadequate levels of inputs application (Sibiko, 2012) and weak managerial capacity present a challenge towards attaining production efficiency (Kleemann *et al.*, 2010) among small scale farmers.

Insufficient knowledge on good agricultural practices (weeds, pests and diseases, watering, manure/fertilizer application, training of vines and pruning management) presents the major management challenges in passion fruit production (Mbaka *et al.*, 2006; Kleemann *et al.*, 2010; Wangungu *et al.*, 2010). Farmers are mostly attracted by the high market prices of the fruit which leads to investment decision based on partial information;

some therefore fail to take note of the challenges faced in growing the crop. Management of the passion fruit orchards differ from one area to another (Dirou, 2004). Although passion fruit's lifespan is 5 to 7 years (Acland, 1971; Morton, 1987), in Kenya it has reduced to an average of 2 to 3 years due to numerous biotic and abiotic constraints.

The aim of the present study was to compare the technical efficiency and orchard management of passion fruit farmers in three producing Counties (Meru, Embu and Uasin Gishu Counties) in Kenya in order to determine opportunities for improving orchard management to enhance productivity at the farm level.

## **2. Materials and Methods**

### *2.1 Study area*

The study was undertaken in the Central-Eastern highlands (consisting Meru and Embu Counties) and North-Rift highlands (Uasin Gishu County). According to the most recent statistics (KNBS, 2010; GoK, 2012), Meru County measures 6936 Km<sup>2</sup>, has a population of 1,356,301 persons and borders Tharaka Nithi County to the South-East, Isiolo County to the East and North, Laikipia to the West and Kitui to the East. Embu County covers 2818 Km<sup>2</sup>, has a population of 516,212 persons and borders Kirinyaga County to the West, Kitui County to the East, Machakos to the South and Meru to the North. Uasin Gishu County measures 3345.2 Km<sup>2</sup>, has a population of 894,175 people and borders Trans-Nzoia to the North, Kericho to the South, Elgeyo Marakwet to the East and Bungoma and Nandi Counties to the West. The three Counties have an altitude of above 1050m asl, temperature range of 8.4-27°C and bi-modal rainfall (long rains start from mid March to late May and short rains starts from mid October to late December) ranging 500-2600mm per annum (GoK, 2012). The study was undertaken in the high potential agro-ecological zones of each County (>1200m asl, ≤18°C and ≥1000mm rainfall annually) (Leeuw *et al.*, 1989) which are suitable for passion fruit farming mainly the purple variety. The main economic activity in the study Counties is Agriculture, dominated by mixed farming systems (GoK, 2012). The areas are highly favorable for passion fruit production with adequate well distributed rainfall, suitable temperature regimes and good soils. The passion fruit farmers in these areas mainly grow the purple variety which is best suited to this agroecology. However, the areas have experienced low average productivity and decline in passion fruit production. The Rift and Eastern regions passion fruit production declined from 18864 and 9663 ton in 2006 to 14505 and 3059 ton in 2010, respectively (HCDA, 2011). Farmers in these areas are also involved in maize, dairy, coffee, tea and mangoes among others.

### *2.2 Data and sampling design*

A multi-stage sampling design was employed. In the first and second stages, three Counties and two districts from each County were purposively selected based on their importance as major passion fruit growing areas. Eldoret East and West, Embu East and West, and Meru Central and Imenti South districts were selected from the three Counties. All the divisions within each selected district formed the clusters for the study. Simple random sampling method was used to select two divisions from each district. Then a systematic random sampling at an interval of 1 respondent was used to select a sample from each cluster to be used for the study. Every second passion fruit farmer was selected. Respondents were identified with the assistance of Ministry of Agriculture extension officers. The sample size of farmers used in the study was determined proportionately using the respective total population of the Counties that is 53, 48 and 22 farmers from Meru, Uasin Gishu and Embu County, respectively.

Data collection was done between July and August, 2012 using a personally administered structured questionnaire. The questionnaire instrument availed household, input, management and output data for one year (May 2011 to June 2012) which were used for managerial and efficiency analysis. The sampling frame constituted farmers who had 0.04 to 3 ha of their farms under passion fruit production.

### *2.3 Data Analysis*

#### *2.3.1 Stochastic frontier analysis*

Stochastic frontier production method in STATA 11 was used to establish the relationship between the passion fruit output and the inputs used by the selected farmers and determination of technical efficiency. Technical efficiency referred to a measure of input-output transformation to assess the ability of a farmer in conversion of inputs to quality output. Output was the dependent variable while inputs were the independent variables. The choice of the stochastic frontier as the tool for analysis in this study was informed by variability of passion fruit production which is attributed to climatic conditions, insect pests, and diseases. On the other hand, data gathered from smallholder farmers is usually inaccurate because they do not keep up to date records; accuracy depends on the farmer's recall capability (Ajibefun, 2002; Kibaara, 2005; Nchare, 2007). The stochastic frontier method also simultaneously took into account the random error and the inefficiency component in estimating a frontier function (Aigner *et al.*, 1977). The Cobb Douglas functional form of the stochastic frontier was employed

because its appropriateness in computation and interpretation. Natural logarithms (ln) were used to correct for heteroscedasticity in the cross-sectional data.

The stochastic frontier model adopted in the study is as used by Aigner *et al.* (1977) based in an imperfect world (world with errors) which is an extension of the basic production function. It is comprised of output and input(s). The function is expressed as;

$$Y_i = f(x_i; \beta) + \varepsilon_i \dots \dots \dots (1)$$

Where  $i=1, 2, \dots, N$ ,  $Y$  is the output,  $\beta$  are unknown parameters to be estimated,  $x$  are inputs and  $\varepsilon$  (error term) =  $v_i - \mu_i$  (upon decomposition),  $\mu$  ranges from 0 to 1.

A decomposition approach is employed to measure the TE in passion production whereby the  $\varepsilon_i$  is decomposed to  $v$  (random error that represents the random variability of passion production that cannot be influenced by farmers) and  $\mu$  (non-negative random variable associated with technical inefficiency in production). The  $v_i$  and  $\mu_i$  terms are assumed to be independently and identically distributed as  $N(0, \sigma_v^2)$  and half-normal  $N(0, \sigma_\mu^2)$ . A Cobb Douglas stochastic frontier function with the decomposed term was defined as;

$$\ln Y = \beta_0 + \sum_{i=1}^7 \beta_i \ln X_i + v - \mu \dots \dots \dots (2)$$

Therefore, estimation of the stochastic frontier production model using maximum likelihood technique was as follows;

$$\ln Y = \beta_0 + \beta_1 \ln \text{seedling number} + \beta_2 \ln \text{passion farm size} + \beta_3 \ln \text{fertilizer} + \beta_4 \ln \text{manure} + \beta_5 \ln \text{pesticide} + \beta_6 \ln \text{hired labour} + \beta_7 \ln \text{family labour} + (v - \mu) \dots \dots \dots (3)$$

### 2.3.2 Managerial analysis

Orchard management scores for each selected farmer and County were determined using a management scale of 1-5 to award scores where 1 and 5 represented poor to excellent orchard management, respectively. Scores were awarded to various management practices (training of vines and pruning, weeding, disease management, watering and manure/fertilizer application) in the three Counties. Mean management scores were separated using Tukey's B test at 5% level of significance due to its ability to show significant differences decisively (Table 3).

In order to determine whether orchard management practices influenced passion fruit farmers' technical efficiency, a multiple regression was run. Farmers' TE (determined using stochastic frontier model) was the dependent variable while management practices were the independent variables. T-test at 1, 5 and 10% significance levels was used to test the hypothesized relationship (Table 4). The hypothesized relationship was as follows;

$$TE_i = \beta_0 + \beta_1 \text{training of vines and pruning} + \beta_2 \text{weeding} + \beta_3 \text{disease management} + \beta_4 \text{watering} + \beta_5 \text{manure \setminus fertilizer application} + \varepsilon_i \dots \dots \dots (4)$$

## 3. Results and Discussion

### 3.1 Stochastic frontier

Technical efficiency (TE) for each passion fruit farmer and mean TE for each County (Table 2-appendix) were determined. In order to ensure homogeneity, the cross-sectional data for the study were converted into natural logarithms at the base of 10. The results (Table 1) showed that number of seedlings used per hectare were significant in Embu and Meru at 1% level and Uasin Gishu County at 5% significance level and thus constituted a key determinant of TE in the Counties. Manure was also significant at 1% significance level in Embu and Uasin Gishu while family labour was significant at 1% and 10% level in Embu and Meru Counties, respectively. Passion farm size and pesticides were only significant at 5% level in Embu County while fertilizer was significant in Meru County. The disparities in the results could be explained by the farmers' differing managerial practices which resulted to differences in productivity of orchards and TEs in the three Counties. The average passion fruit productivity for Embu, Meru and Uasin Gishu Counties was 4200.50, 9766.57 and 8751.35 kg ha<sup>-1</sup>, respectively.

The results (Table 2) showed that TE for Uasin Gishu County ranged from 17 to 85% with a mean of 57%. In Meru County, the farmer with the lowest technical efficiency had 18% while the most efficient had 86% TE and a mean of 65%. In Embu County, the farmer with the highest technical efficiency had 67% while the lowest had 23% against a mean of 47% for the County. The mean TEs implied that only 57, 65 and 47% of the possible output was being realized in Uasin Gishu, Meru and Embu Counties, respectively. It also implies that passion fruit farmers could reduce their inputs by 43, 35 and 53% in Uasin Gishu, Meru and Embu Counties, respectively, without reducing their current output by improving their TEs. These deviations could be attributed to poor utilization of the available resources and other extraneous factors (climate, soils and topography). Further, in Meru, Embu and Uasin Gishu Counties, if the average farmers would attain the TE levels of the most efficient farmers in the Counties, cost savings of 24, 30 and 33%, respectively, would be realized on the current passion fruit production costs incurred {that is [(1 - 65/86) \* 100], [(1 - 47/67) \* 100] and [(1 - 57/85) \* 100]} respectively (Nyangaka *et al.*, 2010). This potential cost saving in production costs would translate into higher profit margins for the passion fruit farmers through reduced resources wastage (optimization).

### 3.2 Analysis of orchard managerial practices

The results (Table 3) showed that training of vines and pruning, weeding and watering mean scores were significantly different for Embu, Meru and Uasin Gishu Counties. Manure and fertilizer application scores also indicated significant differences between Embu and Meru, and Embu and Uasin Gishu Counties. On overall, training of vines and pruning, weeding, watering and manure/fertilizer application had a positive significant relationship with TE as shown in Table 4 (appendix).

Meru County consistently scored higher mean management scores for all evaluated practices than Uasin Gishu and Embu Counties. Mean technical efficiency and productivity were also highest in Meru County followed by Uasin Gishu and Embu Counties. This trend could be attributed to regular weeding (at least once a month) which reduced competition for nutrients between weeds and passion fruit plants (Joy, 2010). Watering during dry seasons ensured that the plants were able to convert fertilizers applied into usable nutrients. It also enhanced assimilation and cooling thus reduced withering. This is so because passion fruit are shallow-rooted and prone to stress during dry seasons (Joy, 2010). Watering of passion fruit orchards could have thwarted the effects of dry periods experienced during the months of August-September and January-February in the Central-Eastern and North-Rift Highlands. Watering may also have boosted flowering and fruiting and minimized fruit drops translating to higher productivity (COLEACP, 2011). Meru County had the highest water use at the farm level among the three Counties thus higher passion fruit orchard watering scores.

COLEACP (2011) explains that training of vines and pruning reduces tangling and congestion, removes deadwood, increases aeration within the canopy and distribution of light (sun), and reduces pest abundance. Farmer adoption of these practices may have led to better performance of the plants in terms of flowering and production of passion fruits in Meru County.

The high scores recorded in Meru for manure/fertilizer application signifies the benefits of this practice; easy access and use of manure and fertilizers ensured passion fruit orchards were supplied with the required nutrients. Good knowledge about a management practice could imply better access to agricultural information, which ensured optimality and eventually reducing wastage of inputs. Good knowledge in management practices contributes to higher technical efficiency as observed by Bakhsh and Hassan (2006) in Punjab, Pakistan. Easy access and use of manure could be attributed to crop-livestock farm enterprise diversification which promoted their interdependence.

Disease management presented the biggest challenge among the farmers in the study areas. Most passion fruit diseases (woodiness virus, *Fusarium wilt* and dieback) have been reported to be complex and highly infectious (Mbaka *et al.*, 2006; Wangungu, 2012). In addition, farmers lack adequate information and skills to effectively control these diseases especially the more recently encountered dieback that has not been well researched on (Mbaka *et al.*, 2006; Kleemann *et al.*, 2010; Wangungu *et al.*, 2010). This may explain the low level of disease management scores across the three Counties.

The differing orchard management practices scores at the farm level were compared to individual passion fruit farmers TEs (Table 4). The multiple regression results (Table 4) showed that all the orchard management practices significantly influenced TE but at varying significance levels. Training of vines and pruning ( $p=0.001$ ), and watering ( $p=0.002$ ) practices positively influenced TE at 1% significance level. Weeding ( $p=0.045$ ) and manure/fertilizer application ( $p=0.075$ ) positively influenced TE at 5% and 10% significance levels, respectively. Only disease management ( $p=0.091$ ) influenced TE negatively at 10% level. This implied that the current disease management methods practiced by the farmers were ineffective thus reducing their technical efficiencies. The significant relationship between the orchard management practices and TE implied that good management practices at farm level are crucial in attaining efficiency (Bakhsh and Hassan, 2006; Galanopoulos *et al.*, 2006). This would ensure better maintenance of orchards thus extends an orchard's life span.

#### 4. Conclusion and Recommendations

The results of the study showed a direct relationship between orchard management and technical efficiency across the three Counties. To improve technical efficiency it is thus necessary to address orchard management practices.

Farmers in Embu County were determined to have the highest scope for improving the efficiency levels and reducing production costs followed by Uasin Gishu and Meru. None of the farmers selected in the study was technically efficient. Therefore, farmers in the three Counties have a high scope of lowering their production costs and realize higher profit margins with improved technical efficiencies.

A key area of intervention is strengthening capacity of passion fruit farmers in the three counties to more effectively manage diseases which are the leading cause of yield losses.

Policy makers should focus on pioneering effective institutional arrangements that would enhance extension access by farmers through deployment of participatory methods such as lead-farmer model, use of group training approach, farmer-driven extension demand and or intensification in the use of the extensive mass media available in the passion fruit producing regions that would supplement and complement the efforts of the few extension workers in availing information. More education on input access and use, and good orchard management practices could improve farmers' production efficiency.

Differences in technical efficiency levels and management scores across the Counties provide a platform for sharing of ideas among farmers. For example, farmers from Embu and Uasin Gishu can learn from Meru County on better managerial practices. The government and private sector agencies can promote cross-border farmer linkages that would enable them to share success experiences through farm visits. This would provide a basis for peer discussions eventually increasing uptake and eventual adoption of passion fruit farming.

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## Appendix

**Table 1: Stochastic frontier production function results for passion fruit orchards in Embu, Meru and Uasin Gishu Counties, Kenya.**

Variables	Embu	Meru	Uasin Gishu
Number of seedlings (number)	1.59*** (0.51)	1.18*** (0.27)	1.02** (0.42)
Passion farm size (ha)	-1.89** (0.75)	-0.37(0.28)	-0.26(0.20)
Fertilizer (kg)	-0.28(0.15)	0.37*** (0.12)	-0.21(0.17)
Manure (kg)	0.11*** (0.03)	-0.01(0.05)	0.71*** (0.27)
Pesticide (kg)	0.10** (0.05)	0.16(0.25)	-0.23(0.21)
Hired labour (person-days)	0.20(0.13)	-0.01(0.01)	-0.06(0.10)
Family labour (person-days)	0.29*** (0.10)	-0.28* (0.15)	0.01(0.14)
_cons	-0.100.70	0.77(0.61)	-1.38(0.81)
Insig2v_cons	-7.90(0.85)	-2.77(0.76)	-2.84(0.51)
Insig2μ_cons	-7.62(132.17)	-0.21(0.33)	-0.60(1.00)
Mean TE	47%	65%	57%

\*, \*\* and \*\*\* significant at 10, 5 and 1 % significance levels respectively. Figures in parenthesis represent standard errors.

**Table 2: Frequency distribution of technical efficiency estimates for a sample of passion fruit farmers in the three Counties.**

TE Range %	Embu		Meru		Uasin Gishu	
	Number	%	Number	%	Number	%
0-25	2	9.09	2	3.77	3	6.25
26-50	11	50	5	9.43	15	31.25
51-75	9	40.91	30	56.61	25	52.08
76-100	0	0	16	30.19	5	10.42
Total	22	100	53	100	48	100
Minimum TE	23%		18%		17%	
Maximum TE	67%		86%		85%	

**Table 3: Orchard management practices scores analyzed using Tukey's B Test.**

Management practice	Embu	Uasin Gishu	Meru
Training of vines and pruning	2.36(0.17) <sup>a</sup>	2.96(0.14) <sup>b</sup>	4.25(0.14) <sup>c</sup>
Weeding	2.68(0.29) <sup>a</sup>	3.33(0.21) <sup>b</sup>	3.94(0.22) <sup>c</sup>
Disease management	2.09(0.29) <sup>a</sup>	2.53(0.21) <sup>a</sup>	2.54(0.22) <sup>a</sup>
Manure/fertilizer application	2.05(0.23) <sup>a</sup>	2.89(0.13) <sup>b</sup>	3.46(0.19) <sup>b</sup>
Watering	1.41(0.18) <sup>a</sup>	2.10(0.15) <sup>b</sup>	3.30(0.22) <sup>c</sup>

Means followed by a different letter along the row are significantly different at  $p=0.05$ . Figures in parenthesis represent standard errors.

**Table 4: Multiple regression results for orchard management practices and farmers' technical efficiency.**

Variables	Coefficient	Standard Error	P>t
TE			
Training of vines and pruning	4.47	1.37	0.001
Weeding	0.34	0.13	0.045
Disease management	-1.76	0.95	0.091
Manure/fertilizer application	2.21	1.14	0.075
Watering	3.02	0.93	0.002
_cons	35.39	4.79	0.000



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